NPS Monitoring Program Landscape Monitoring Workshop
January 27-28, 2004
Ft. Collins, Colorado

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Table 3 from Hansen and Gryskiewicz 2003. Spatial datasets used for characterization of current landscapes and land use change over time.

EPA Landscape Analysis and Assessment Overview

NPS Landscape Monitoring Workshop Agenda – 27-28 January 2004

Tuesday

8:00		Coffee and informal discussions
8:30	John Gross	Introductions, overview, and goals
9:00	Andy Hansen	Land use and cover change: Processes and conceptual models
9:45	Bill Kepner	Indicators of landscape integrity
10:15		Break
10:30	Bob Gardner	Landscape patterns and pattern indices
11:15	Pat Comer	NatureServe: Landscape evaluation and monitoring
12:00		Lunch
1:15	Brad Smith	The USFS FIA program and landscape monitoring
1:45	Brad Reed	The USGS Geographic Analysis and Monitoring (GAM) Program; Assessing the rates, causes, and consequences of landscape change
2:15	Proj leaders	Very brief descriptions of current NPS projects
2:30	All	Discussion on breakout group topics and schedule
3:00	All	Break, then convene breakout groups
4:30-5:00	Grp leaders	Breakout group results
5:00		Social at the Marriott Residence Inn
6:30		Dinner at local restaurant

Wednesday

8:00		Coffee and informal discussions
8:30	John Gross/all	Brief summary and convene breakout groups
10:00		Break
11:30	Grp leaders	Group reports
12:00		Lunch
1:15	All	Breakout groups
3:30		Break
3:45	Grp leaders	Group reports
4:15 - 5:00	All	Summary of proceedings and future actions
6:30		Dinner at local restaurant

Potential breakout groups:

Tuesday PM

Conceptual model evaluation (Hansen)
- Current models
- Terrestrial / aquatic linkages
- What additional models are needed?

Landscape pattern indicators (Gardner)
- Patch definition
- Fragmentation and linear features (patch detection and definition)
- Scale and metrics

Wednesday

Conceptual model evaluation and development (continued)

Existing products and interagency collaboration
- Nonimagery data on land use and land cover
- Spectral data
- Improved products

Landscape change and change detection
- Programs and databases
- Analysis of change

Cross-system evaluation
- Utility of indicators and data across biomes, parks of different sizes, and contexts

Other potential breakout group topics:
Indicators for disturbance and catastrophic events
Terrestrial - aquatic linkages
Landscape indicators for coastal ecosystem

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January 27-28, 2004, Ft Collins, CO

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NPS I&M Landscape Monitoring Workshop Participants
January 27-28, 2004, Ft. Collins, Colorado

Phyllis Adams has served as the NPS Midwest Region I&M Coordinator since October 2000. Prior to that worked for the Bonanza Creek Experimental Forest Long-Term Ecological Research Program at the University of Alaska for 12 years. In this position I worked within an interdisciplinary team of researchers studying many aspects of boreal ecosystems. I designed and implemented studies to assess vegetation succession and change resulting from natural and anthropogenic stressors and to quantify environmental changes accompanying vegetation development. One objective of this research was to describe the structure and composition of boreal plant communities and shed light on processes that resulted in the mosaic of high latitude forests. My formal training includes landscape ecology, plant community ecology, botany, natural resources management, and forest technology. I also have a degree in statistics with courses that focused on the analysis of spatial and temporal patterns of vegetation that reflect underlying biological processes. I received my Ph.D. in landscape ecology from Duke University in 1999. My dissertation included quantifying landscape changes resulting from fluvial deposition and relating those changes to river discharge and effects on vegetation succession. I also investigated the spatial variability in floodplain ecological processes using spatial analyses such as partial Mantel's tests and Ripley's K point analysis.

Marc Albert is a Natural Resource Specialist working with the Northeast Coastal and Barrier Network. Prior to working in the Northeast Region, I coordinated vegetation management and habitat restoration in the Presidio of San Francisco, part of the Golden Gate NRA. I have experience in ground-based vegetation monitoring and management, but remote sensing / landscape monitoring / veg mapping are relatively new to me. I will be working this year with a group that will develop the Protocols for the Land Cover Change Vital Signs for our network. In particular, we are interested to find out if we can utilize remote sensing data to detect the presence of intertidal habitats and submerged aquatic vegetation. In addition, we would like to assess the potential for detecting exotic invasive plant populations and visitor impacts such as social trails using remote methods.

Leslie Armstrong Leslie has served as the National Park Service GIS program manager, in Denver, since 1993. She came to the National Park Service in 1991 from the Defense Mapping Agency, where she worked for ten years with Latin America mapping programs and as a technical manager the agency's modernization program. Now as the Chief of the GIS Division, Leslie manages acquisition of software and spatial data including satellite imagery, develops GIS policy, training, enterprise architecture and directs GPS activities. Leslie and the GIS Division developed and implemented the first NPS web site, spatial data clearinghouse, and most recently the NPS Interactive Map Center. Leslie finished her BA in Psychology and Spanish (with minors in Geography and History) and was a graduate student in Geography at South Dakota State University.

J. Lane Cameron has been the Monitoring Coordinator for the Mediterranean Coast Network of parks in Southern California since July of 2002. Lane received his MS and BS degrees from Brigham Young University (Provo, UT) and his PhD from Simon Fraser University (Burnaby, B.C., Canada). After completing his PhD, Lane worked as a research associate in the Department of Larval Ecology at Harbor Branch Oceanographic Institution, Ft. Pierce, FL. He was instrumental in developing a research program on the ecology of reproduction and larval development of deep-sea invertebrates. After fours years at Harbor Branch, Lane turned to the private sector working as an environmental consultant, data manager, and project manager for Dames & Moore, Inc., Seattle, WA, on numerous projects including the Exxon Valdez Oil Spill, the Tampa Bay Oil Spill, and two multimillion dollar contracts from the USDA Forest Service to produce Environmental Impact Statements for timber sales in Southeast Alaska. Immediately prior to joining the National Park Service in January of 2001as the Biological Inventory Coordinator and acting Monitoring Coordinator for the Greater Yellowstone Network, he worked as Director of Operations and Research for two aquaculture firms in Hawaii.

Kent Cavender-Bares, a Fellow with the H. John Heinz III Center for Science, Economics and the Environment, is one of two staff scientists for the Environmental Reporting program. At the Center, Kent has worked on many aspects of *The State of the Nation's Ecosystems* project, including interacting with data providers and both technical and non-technical writing; most recently he has spearheaded a full update of the report's website. Over the past several months, Kent has devoted a considerable effort to convening a Task Group to improve the suite of landscape pattern indicators in *The State of the Nation's Ecosystems* report targeted for release in 2007. This group just concluded its second meeting and expects to meet one or more times over the next year. Before joining the Center in 2000, Kent received his Ph.D. from the Massachusetts Institute of Technology, for which he studied the ecology of marine phytoplankton. Kent holds engineering degrees from Stanford and Cornell and has had work experiences ranging from agricultural waste management to manufacturing engineering.

Warren Cohen is a Research Forester with the Pacific Northwest Research Station of the USDA Forest Service and Director of the Laboratory for Applications of Remote Sensing in Ecology at the Corvallis Forestry Sciences Lab in Oregon. His PhD (1989) is from Colorado State University, in Forest Science, with emphases on remote sensing and wildland fire behavior. Warren conducts research in remote sensing and related geographic and ecological sciences. His primary focus is translation of remote sensing data into useful ecological information, with significant activity in analysis and modeling of vegetation structure and composition across multiple biome types. Currently, Warren's research involves spatially-explicit modeling of ecological processes with significant attention to scaling from fine to coarse grain. He is a courtesy Professor in the Department of Forest Science at Oregon State University, where he intermittently teaches a graduate level remote sensing and landscape ecology course, advises graduate students as both major and minor professor, serves on interdepartmental committees, and gives guest lectures and seminars. Warren is on the editorial board of the journal Remote Sensing of Environment.

Pat Comer completed graduate work in Forest and Landscape Ecology at the University of Michigan, Ann Arbor in 1987. Throughout much of the 1990s, he worked as an ecologist with The Nature Conservancy's Michigan Natural Features Inventory. There he completed extensive research, inventory, mapping, and consultation on forest, wildlife, and environmental management and monitoring. Among other projects, Pat led an effort to map the vegetation of Michigan circa 1800 using historical records, then assessed trends in major ecosystems through the 1980s. From 1998-2000, Pat was Senior Regional Ecologist for TNC, based in Boulder, Colorado. There he focused on practical methods for ecoregional assessment, applied across western North America. Pat currently oversees the Terrestrial Ecology Department of NatureServe and works on core methodology and products for the network of Natural Heritage programs, including the development and application of the new Terrestrial Ecological Systems Classification for the Americas for mapping and ecological monitoring. He maintains involvement with development and implementation of the U.S. National Vegetation Classification and parallel efforts in Canada and Latin America. Pat is engaged in several U.S. regional-scaled projects with the Gap Analysis Program, interagency sagebrush ecosystem projects, USDA Forest Service, and NASA.

Samuel E. Drake is currently an Assistant Research Scientist in the Arizona Remote Sensing Center, a unit of the Office of Arid Lands Studies at the University of Arizona in Tucson. He received the PhD in Arid Lands Resource Science from the University of Arizona in 2000, with a minor in Remote Sensing and Spatial Analysis. He holds a MS in Renewable Natural Resource Studies, also from the University of Arizona, and a BA in Zoology from the University of California at Berkeley. His current research is focused on the application of high spatial resolution satellite imagery to vegetation mapping and monitoring in Sonoran Desert Network national parks. This is part of his wider interest in applying remote sensing and GIS tools to resource management decision making. He has served two tours in the U.S. Peace Corps, working in aquaculture in Cameroon and in Forestry in Benin, and has participated in geospatial research projects in Malawi and Rwanda.

Robert H. Gardner has been a professor landscape ecology since joining the faculty at the Appalachian Laboratory, University of Maryland Center for Environmental Science (UMES) in 1994. Current research interests include the development of new methods for predicting ecological dynamics in spatially heterogeneous systems, implementation of risk-based approaches for assessing effects of natural disturbances, and issues of and-use and global change on sustainability of ecological systems. Gardner has published over 150 manuscripts and texts, including _/Landscape Ecology in Theory and Practice: Pattern and Process/_ with M. G. Turner and R. V. O_Neill and the volume _/Scaling relations in experimental ecology/_ co-edited with colleagues at UMES. Quality of life is assured by keen interests in many outdoor activities, recreational readings in history and philosophy, and diligent avoidance of administrative duties of any kind.

John E. Gross is an Ecologist with the NPS Monitoring Program, in Ft. Collins, Colorado. John has a B.A. in Environmental Biology (Univ. Colorado, Boulder), M.S. in Zoology (Colorado State University), and Ph.D. in Ecology (Univ. California, Davis). He was a post-doc and Research Scientist with the Natural Resource Ecology Laboratory, Colorado State University 1990-1999, and a Landscape Ecologist with CSIRO's Division of Sustainable Ecosystems from 1999-2003. He joined the Monitoring program last year and has an appointment as a Senior Research Scientist with the Natural Resource Ecology Laboratory, Colorado State University. John's research interests include conservation biology, population and disease dynamics, and systems ecology, and his projects have developed, tested, and applied ecological models over a broad range of scales. John’s recent projects have addressed problems that ranged from the application of complex system science to investigate rangeland social-ecological systems to adaptive management of brucellosis in the Greater Yellowstone area. John is coordinating activities in the NPS Monitoring Program to evaluate monitoring of land use and land cover change, and helping the program better integrate remotely-sensed data into monitoring programs. He has served on many national and international panels, including the National Academy of Sciences panel on dynamics of Yellowstone National Park, and the Heinz Center Working Group on landscape pattern.

Andy Hansen is Professor in the Ecology Department at Montana State University. He teaches introductory ecology to undergraduates and landscape ecology to graduate students. His research focuses on how to sustain both natural ecosystems and the surrounding human communities. While on the faculty of Oregon State University, Dr Hansen evaluated how new forest management approaches influenced both wildlife and wood production. At Montana State University, he has examined rates of private lands development in Greater Yellowstone and consequences for forest wildlife in protected areas like Yellowstone National Park. Results from the GYE provided the basis for comparative study of land use change surrounding several nature reserves and biodiversity within reserves for 6 greater ecosystems around the world. This project laid the basis for a study of regional scale monitoring around the Heartlands National Park Network. Dr. Hansen also led a national study of global change effects on forest biodiversity as part of the U.S. Assessment of Climate Change and Variability. His work uses a combination of remote sensing, computer simulation and field studies. This research is funded primarily by NASA, EPA, conservation organizations, and the timber industry. Homepage: http://www.homepage.montana.edu/~hansen/documents/cvs/andycv.htm

Bruce Jones is Chief of the Landscape Ecology Branch in the US EPA’s Laboratory in Las Vegas, NV. He is involved in landscape ecology research projects in the US, northern Mexico, Russia, central Europe, and Australia. Bruce has been with EPA for 14 years. Previous to coming to work with the EPA, Dr. Jones worked in the Endangered Species Office in Washington, D.C., working on endangered species status reviews and listings within the U.S. and abroad. Bruce received his Ph.D. from the University of Nevada in Environmental Biology in 1995, an M.S. in Ecology from New Mexico State University in 1979, and a B.S. in Biology from Jacksonville University in 1974. He has conducted extensive research in the fields of landscape ecology, biogeography, molecular evolution, and herpetology, and has over 75 publications. Dr. Jones is currently Councilor-at-Large of US-IALE (2002-2004), on the Editorial Advisory Board for the International Journal of Environmental Monitoring and Assessment, a member of the Heinz Center Working Group on landscape pattern, and on a national AIBS working group for the

National Ecological Observatory Network (NEON). He served as President for the Arizona Chapter of the Wildlife Society in 1985.

Robert Kennedy is a Doctoral candidate in the Department of Forest Science at Oregon State University, and the Co-Director of the Laboratory for Applications of Remote Sensing in Ecology at the Corvallis Forestry Sciences Lab. Together with Warren Cohen, I will be developing protocols for remote-sensing based ecological monitoring in the North Cascades and Coast Network through 2004 and early 2005. My interests lie in determining how to scale ecological knowledge from the plots or stands to landscapes and regions, taking into account scaling effects, sampling design, and modeling uncertainties. My Masters degree at the University of Colorado (1994) examined scaling effects on a relationship between field measurements and remotely-sensed data. My PhD project concerns modeled carbon fluxes from forests in Oregon, attempting to quantify the spatial uncertainties in estimated fluxes caused by variation in key leaf-level ecophysiological characters. I will be defending in early winter of 2004. Between degrees, I worked for several years as a remote sensing analyst at Oregon State University, focusing both on technical remote sensing issues and on interactions between remote sensing and ecology.

William (Bill) G. Kepner is a Research Ecologist for the U.S. EPA, National Exposure Research Laboratory in Las Vegas, Nevada. He is responsible for the research and development of landscape pattern indicators and their incorporation into regional assessment programs to measure ecological and watershed condition at a variety of scales. Tests of the indicators are being conducted in small community-based watershed in southeast Arizona and northern Sonora, Mexico (see http://www.epa.gov/nerlesd1/land-sci/san-pedro.htm); regional application across five southwestern states via the USDI Regional GAP analysis (see http://www.epa.gov/nerlesd1/land-sci/gap.htm); and internationally via the NATO Committee on the Challenges of Modern Society (see http://www.nato.int/ccms). Prior to his present role, Bill served as Acting Deputy Director for the Environmental Sciences Division, Acting Branch Chief for the Environmental Chemistry Branch and as the Technical Director of the EMAP Arid Ecosystems Program (aka EMAP-Rangelands). In addition to providing scientific direction, his responsibilities included strategic planning, budget, program implementation, interagency coordination, and analysis, reporting, and presentation of data. He has received both the EPA Silver and Bronze Honor Awards. Previous to his employment with the EPA, he was employed by the U.S. Fish and Wildlife Service in Phoenix, Arizona where he developed a statewide program to evaluate the impacts of environmental contaminants on fishery and wildlife resources. Bill started his career as a Wildlife Biologist in the U.S. BLM where he conducted nongame vertebrate inventories in western Arizona. His awards include the Unit Citation Award for Excellence of Service by the Secretary of the Interior (1980), and the Doug Morrison Memorial Award for Outstanding Wildlife Biologist in Arizona (1982, 1998). Bill received an A.A. Degree in Biology from Phoenix College in 1973, a B.S. Degree in Biology from the University of Arizona (Tucson) in 1975, a M.S. Degree in Zoology from Arizona State University (Tempe) in 1982, and a MPA in Public Administration from the University of Nevada Las Vegas (UNLV) in 2000.

Chris Lauver is currently serving as the quantitative ecologist for the Southern Colorado Plateau I & M Network of the NPS, based in Flagstaff, AZ. Before his current position, he was a range management specialist for nearly 2 years for the Wasatch-Cache National Forest in Utah. During 1987 to 2002, Dr. Lauver was a scientist for the Kansas Biological Survey, an ecologist for the Kansas Natural Heritage Program, and served as adjunct faculty at the University of Kansas. His research interests include the integration of field and remotely sensed data to identify and analyze natural areas and rare species habitat. His publications include articles on the use of digital satellite imagery to identify high quality grasslands, testing a GIS model of bird habitat suitability, and a hierarchical classification of the natural vegetation of Kansas. While in Kansas, Chris served as a co-PI in developing the Land Cover Map for the Kansas Gap Analysis project.

Mark Miller is a research rangeland ecologist with the U.S. Geological Survey in Moab, Utah. He has a Ph.D. in plant ecology and soils from the University of Colorado (2000). His research interests include plant-soil relations and effects of land use and climate on dynamics of dryland ecosystems. Prior to joining the USGS in October 2003, he worked as an ecologist for the Bureau of Land Management (Grand Staircase-Escalante National Monument) and the National Park Service (Northern Colorado Plateau Network). In addition to his work for government agencies on the Colorado Plateau, he has several years' experience conducting environmental-impact studies in Arctic Alaska.

Bryan Milstead began work with the National Park Service in February 2001 as the Ecological Monitoring Program Coordinator for Organ Pipe Cactus N.M. In May 2002 he became the Coordinator of Northeast Coastal and Barrier Network. He is currently duty stationed at the University of Rhode Island and is an adjunct professor in the Department of Natural Resources Science. Bryan received his Bachelor's degree from Southwest Missouri State with an emphasis on aquatic entomology. He completed his Master's Degree at the University of Oklahoma where he studied predator-prey interactions in springs. His doctoral work at the Northern Illinois University focused on the Landscape Ecology and Population Genetics of irruptive small mammal species in North-central Chile. He has an active interest in using GIS and remote sensing technology in Natural Resource Monitoring programs.

Sunil Narumalani is an Associate Professor in the School of Natural Resources and is a faculty associate at the Center for Advanced Land Management Information Technologies (CALMIT). He received his Ph.D. in Geography, from the University of South Carolina in 1993. Dr. Narumalani teaches courses in remote sensing (digital image analysis) and advanced geographic information systems. His research focuses on the use of remote sensing for the extraction of biophysical information from satellite data and aircraft multispectral scanner systems, integration of geospatial data sets for ecological and natural resources mapping and monitoring, and the development of new image processing analyses techniques for information extraction. Over the past four years, Dr. Narumalani has worked on several projects with the Nebraska Army National Guard (NE ARNG) and has provided training in remote sensing and GIS to the 3436^{th} Military Intelligence Detachment of the U. S. Army.

Thom O'Dell is the Inventory and Monitoring Program Manager for the Northern Colorado Plateau Network. He has a B.S. in Biology (The Evergreen State College) and a Ph.D. in Botany and Plant Pathology (Oregon State University). He was NSF Postdoctoral Fellow and a research scientist in the Department of Botany, University of Washington where he studied fungal communities on a precipitation gradient in Olympic National Park. He was regional mycologist for the USDA the Forest Service, Pacific Northwest Region, coordinating surveys, management, and monitoring of rare fungi over the range of the northern spotted owl. From 2001 to 2003 he was science program administrator, Grand Staircase – Escalante National Monument BLM. Thom has an Adjunct Faculty appointment with the Biology Department, Northern Arizona University. His recent research includes ecology and population genetics of fungi, and edaphic and disturbance effects on mycorrhizal fungi.

Dennis Odion is a vegetation ecologist who specializes in fire. He received his masters degree in botany (1984), and his doctoral degree (1995) in plant geography, both from UC Santa Barbara. His dissertation research was on spatial variation in fire severity, and how this influenced the formation of local vegetation patterns. While at UC Santa Barbara, Dennis also mapped and conducted research describing desert vegetation, oak woodlands, and chaparral. From 1995-2000, Dennis was the vegetation ecologist for a large land management agency in northern California, the Marin Municipal Water District. Duties entailed fire, and rare and exotic species management. More recently, Dr. Odion has conducted research on landscape level fire severity in the Klamath region and Sierra Nevada, and on prescribed burning and the ecology of rare plants. He is presently researching how fire affects the susceptibility of landscapes to Sudden Oak Death Disease. Dennis resides in Ashland, Oregon and maintains a research affiliation with UC Santa Barbara.

Elijah Ramsey III is the Remote Sensing Team Leader and a Principle Investigator at the National Wetlands Research Center at Lafayette, Louisiana. The National Wetlands Research Center is part of the Biological Resources Division of the USGS. Research specialties involve applied and theoretical remote sensing and geographical information systems, environmental chemistry and water quality and oceanography, and experience in hydrology, programming, and statistical analysis. Elijah gained his B.S. (Chemistry) at Oregon State University, his M.S. (Geophysical science) at Georgia Institute of Technology, and doctorate in geography at the University of South Carolina. He has worked with the National Wetlands Research Center since 1989. Elijah and his remote sensing team have completed and published the results of two National Park Service landholdings reports distributed on hardcopy and CD's, and as a Manuscript in an international journal. His team is completing a historic landcover classification from 1934 to 2000 of the Palo Alto Battlefield National Historic Site providing the first high spatial resolution (0.5 m) and highly detailed classification of the recently enacted historic site. The current landcover and landuse will be transferred back through time (about every 20 yr) to 1934 in order to show what has changed in the Site landscape. Recently, he served as a research member of the Science Validation Team of the NASA-USGS Earth Observing-1 Mission Instrument Performance Evaluation and Data Validation Program, Goddard Space Flight Center, Washington D.C. He serves as a Trustee of the Coastal Education and Research Foundation (2002) and associate editor of the Journal of Coastal Research. He is an adjunct professor in the Department of Geography and Anthropology, Louisiana State University, Baton Rouge, Louisiana and has written an extensive and detailed chapter covering all aspects of remote sensing of coastal environments in Encyclopedia of Coastal Science Series, Kluwer Academic Publishers, The Netherlands (in press).

Brad Reed is a Principal Scientist at the USGS EROS Data Center is Sioux Falls, South Dakota. He has a Ph.D. in geography with an emphasis in remote sensing from the University of Kansas (1990). He has been involved in research using moderate resolution remote sensing for land cover characterization and monitoring for the past 15 years. He was Project Leader for the IGBP global land cover characterization project and has worked on phenological characterization for over 10 years. His team developed one of the widely used remote sensing - based phenology databases of the U.S. He has served on several national and international scientific committees and panels (e.g. Global Observation Information Network and International Steering Committee on Global Mapping) and was a Visiting Scientist at the Joint Research Centre of the European Commission (Ispra, Italy) in 1996. Dr. Reed has been the EDC Land Processes DAAC representative to the MODIS Science Team since 1997.

Hildy Reiser is the new I & M Program Manager for the Chihuahuan Desert Network. She came to the NPS last fall via the Department of Defense, Holloman AFB, NM, where she was the Natural Resources Manager for 9 1/2 yrs. Hildy has also worked for the US Forest Service, US Fish & Wildlife Service, and was a cooperative student with the NPS (for Voyageurs NP, MN) while working on her Ph.D. Hildy earned her Ph.D from Northern Arizona University, M.S. from the University of Wisconsin-Madison, and B.A. from the University of Texas at Austin. Her research and management interests include impact of disturbances on desert ecosystems, and avian and wildlife ecology, especially in the context of management and conservation problems. She is active in The Wildlife Society and other organizations. Hildy and her husband (Dr. Pat Ward) enjoy traveling, bird-watching, white water river rafting, and other outdoor activities.

Robert Rothwell is a project coordinator with the Center for Advanced Land Management Information Technologies (CALMIT) at the University of Nebraska - Lincoln. Presently, he is working on a NPS Prairie Cluster LTEM study of long term land use/land cover change. He is also coordinating the Planning Level Surveys/GIS projects at three Army National Guard sites in Nebraska. Rob graduated from UNL School of Natural Resources with a BS Range Management. He also completed the GIS Certification Program at UNL in the Department of Geography. Before Rob came to CALMIT he was involved in various operations and studies of range ecology in the Nebraska Sandhills He has had considerable experience in the practical applications of management strategies in the beef cattle business. Rob has accumulated valuable knowledge in image interpretation techniques and GIS database management.

Greg Shriver is Inventory and Monitoring Coordinator of the Northeast Temperate Network, which includes 10 National Parks and the Appalachian Trail. He is broadly interested in applied ecology and conservation biology, especially in determining the effects of human habitat alterations on animal populations and working towards integrating science into management policy. Greg earned his M.S. in Wildlife Conservation from the University of Massachusetts and Ph.D. in Conservation Biology (SUNY, Syracuse, 2002). He joined the National Park Service after a post-doc with the Wells National Estuarine Research Reserve developing salt marsh restoration monitoring protocols to be implemented throughout the Gulf of Maine. Greg's dissertation work was also in salt marsh ecology where he established research at multiple spatial and organization scales. At the landscape scale, he coordinated an inventory of 235 salt marshes in New England and used the inventory data to determine if landscape context influenced patterns of avian species richness and area requirements for breeding birds. At the species level, he investigated the breeding ecology and level of introgression between two species of sharp-tailed sparrows. He is also interested in the effects of roads on wildlife populations and developing and implementing long-term monitoring programs.

Kevin L. Skerl, (MS Conservation Biology from U. of Maryland; BS Wildlife Biology from Ohio University) CUVA ecologist since October 1998. Has utilized landscape ecology and GIS/RS for gypsy moth monitoring and management, riparian and wetland buffer programs, deer inventory/monitoring projects, research design and agricultural compliance/planning activities during work at CUVA. Previously applied these tools for international bird conservation for three years in The Nature Conservancy's Latin America and Caribbean Division. Assessed landcover/habitat values of potential migration corridors and wintering sites for the most recent Whooping Crane reintroduction project. Worked editing satellite imagery classifications for a NASA tropical forest change detection project at the Unviersity of Maryland. Current park research involves an assessment of the effects landscape composition and structure on white-tailed deer distribution and impacts. Future plans are to utlize newly generated park LULC from 1959 and 2000 in Cuyahoga River watersheds to assess the dynamics and impacts of urbanization on park resources.

Brad W. Smith is Associate National Program Manager for the USFS Forest Inventory and Analysis (FIA), in Washington D.C. He provides budget and policy guidance for the national FIA program. He received his B.S. in Forestry from Purdue University in 1975 and M.S. in Forest Management from Purdue University in 1977. Brad has been with the FIA program for 26 years. Prior to coming to Washington in 1991, Brad spent 15 years at the USFS North Central Research Station in St. Paul Minnesota, developing forest growth models and serving as Timber Products Analysis Group Leader. He currently serves as the National Database Coordinator for FIA, is the Montreal Process inventory specialist for the U.S., the National Correspondent for the United States to the UN FAO Global Forest Resource Assessments, North American Forestry Commission Inventory Working Group specialist, and ex-officio member of the Canadian Forest Inventory Committee.

David Theobald is a geographer and landscape ecologist interested in understanding patterns of landscape change, the consequences of development on wildlife habitat, especially in the Rocky Mountain west. He received his Ph.D. from the Department of Geography, University of Colorado, Boulder, and his M.A. from Department of Geography, University of California, Santa Barbara. David is a Research Scientist at the Natural Resource Ecology Lab and an Assistant Professor in the Department of Recreation & Tourism at Colorado State University. He also was a David Smith Fellow with The Nature Conservancy. In the past, David has helped to develop the Colorado Natural Diversity Information Source (NDIS), an online source of information for wildlife, habitat, natural communities and plants in Colorado. He also has written and lectured extensively on landscape change in the West, including contributions to the Atlas of the New West, Forest Fragmentation in the Central Rocky Mountains, and Rocky Mountain Futures. David's current research includes developing functional landscape connectivity metrics for the Colorado Department of Transportation; landscape metrics for predicting aquatic resource distributions (for EPA); a GIS-based implementation of a spatially-balanced, variable-inclusion probability sampling design (also for EPA); cross-boundary analysis of protected areas (for Colorado

Division of Wildlife); and developing accessibility maps to predict historical land uses and for developing sampling designs.

Phil Townsend is an Associate Professor at the Appalachian Laboratory of the University of Maryland Center for Environmental Science. His research interests center on watershed hydrology and forest dynamics, and in particular with the application of remote sensing and the modeling of environmental processes to assess fluxes of water, sediments and nutrients from forested and mixed-use watersheds, as well as wetlands. Phil's work emphasizes linkages between ecosystem function (nitrogen and carbon cycling), plant community dynamics, watershed hydrology and landscape ecology. Major tools of the work include remote sensing and GIS as integrated with field measurements. Dr. Townsend's major research projects involve studies of forest species composition in the Shenandoah National Park and the Central Appalachians, testing and validation of new remote sensing technologies for application to ecosystem studies, examination of relationships between sedimentation and changes in flooding on wetland vegetation, and the ecohydrological and landscape impacts of insect defoliation in the Appalachians and Upper Midwest. This research is funded by NASA, NSF, The Nature Conservancy, EPA, USGS and the US Forest Service.

Brad Welch has received a B.S. in Environmental Studies-Chemistry, an M.S. in Water Resources, and a Ph.D. in Natural Resources/Wetland Ecology. His education has been punctuated by experience as an environmental chemist at Cornell University and with a water pollution control firm in Virginia, as a wetland ecologist studying *Phragmites australis* on Lake Erie, and as a visiting assistant professor at St. Lawrence University in New York's Adirondack region. Recently, he has been assisting the San Francisco Bay Area Network with the development of conceptual models and the selection of Vital Signs indicators for the Service-wide Inventory and Monitoring Program. As the NPS Invasive Species Monitoring Coordinator, Brad is assisting the parks and networks in developing standardized protocols, example objectives and justification statements, and enhancing communication among parks, other agencies, organizations, and academia regarding invasive species monitoring. Brad's research interests include using multivariate analysis to define ecological limits that can be used to control invasive species and foster species diversity. Assessment of real versus perceived impacts of invasive plant species on ecosystem structure and function is an inherent part of this pursuit. In his other life, Brad enjoys backpacking, traveling, and general outdoor adventuring with his wonderful wife, Sunita.

Mark Wotawa has been an Ecologist with the NPS Inventory and Monitoring program since 2000, where he serves as the technical coordinator of the Biological Inventories of vertebrate animals and vascular plants for 270 park units. He also coordinates the development and population of the NPS Biodiversity Database, NPSpecies, which is used to store, manage and distribute documented species lists and other products from the biological inventories and other studies in the NPS. Mark has B.S. in Wildlife Biology (University of Alaska, Fairbanks), an M.S. in Quantitative Wildlife Biology (Colorado State University) and extensive graduate level coursework under an M.S. program in Statistics (Colorado State University). Mark's ecological and environmental experience is diverse and prior to the NPS they include field studies of waterfowl, eagles, arctic fox, small mammals and vegetation in Ohio, Alaska and Colorado for state agencies and the USFWS, interpretive work with the National Audubon Society in Kentucky, survival and recovery rate estimation of long-term mallard banding studies in Colorado, data analyses for the quality assurance program of the multi-agency National Atmospheric Deposition Monitoring Network (NADP), biometrics and data management for the USGS Colorado Plateau Research Station at Northern Arizona University, statistical programming for the private sector for long-term compliance monitoring of groundwater at landfills and soil contamination clean-up at superfund sites, and data management on behalf of the USGS Midcontinent Ecological Science Center. Mark's interests include the development and statistical analysis and modeling of primarily large and long-term data sets to solve complex biological and environmental questions.

Arctic
Central Alaska
Southwest Alaska
Southeast Alaska
North Coast and Cascades
Klamath
Northern Semi-Arid
Rocky Mountain
Greater Yellowstone
Northern Great Plains
Great Lakes
Northeast Temperate
Eastern River and Mountains
Northeast Coastal and Barrier
National Capital Region
Mid Atlantic
San Francisco Bay Area
Sierra Nevada
Mojave Desert
Northern Colorado Plateau
Heartland
Cumberland / Piedmont
Southern Colorado Plateau
Southern Plains
Appalachian Highlands
Mediterranean Coast
Southeast Coast
Sonoran Desert
Chihuahuan Desert
Gulf Coast
Pacific Islands
South Florida / Caribbean

Acronyms commonly used in remote-sensing literature

AMSR	Advanced Microwave Scanning Radiometer. New; soil moisture @ 1 km resolution.
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer (10-30 m resolution).
AVHRR	Advanced Very High Resolution Radiometer. 8 km, global NDVI coverage (free)
CIESIN	Center for International Earth Science Information, Columbia University
DEM	Digital elevation model (digital topographic map)
EROS	Earth Resources Observation System. The EROS data center, operated by USGS, is in Rapid City, SD
ETM+	Enhanced Thematic Mapper instrument on Landsat satellite (currently stuffed)
FGDC	US Federal Geographic Data Committee
GEMS	Global Environmental Monitoring System of the UN
IGBP	International Geosphere-Biosphere Programme
IHDP	International Human Dimensions Programme
IKONOS	Space Imaging's satellite – 1 m pan and 4 m multispectral images
LANDSAT	TM images – 80 m before 1984; $\leq$ 30 since.
LCCS	Land Cover Classification System
LIDAR	Light detection and ranging – an active, laser radar with resolution of < 1 m.
LUCC	Land Use and land Cover Change Project (IGBP and IHDP)
MODIS	Moderate Resolution Imaging Spectrometer of NASA. Depending on the product, resolution from 250 m to 8 km. Mostly free.
MRLC	Multi-Resolution Land Characteristics consortium. Collaborative effort to develop and test a national land-cover data set with environmental characteristics. Cover based on Landsat-TM imagery. Currently working 2001 cover.
NASA	US National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index (vegetation greenness)
NLCD	National Land Cover Dataset. Product of MRLC.
NOAA	US National Oceanic and Atmospheric Administration
NSF	US National Science Foundation
QuickBird	Digital Globe's imagery – 0.6 m pan; 2.4. multispectral.
SAR	Synthetic aperature radar.
SPOT	Systeme pour l'Observation de la Terre
TM	Thematic Mapper instrument on Landsat satellites
UN FAO	United Nations Food and Agricultural Organization
UNEP WCMC	World Conservation Monitoring Centre
USGS-BRD	US Geological Survey Biological Resources Division

Landscape vital sign summary
January 2004

The table on the reverse side of this sheet will provide an appreciation for the range and scope of high-priority vital signs (VS) potentially related to landscape-level analyses. Some vital signs are traits that directly index or measure land use or landscape pattern; others contribute to understanding the cause or effects of landscape change, or they may be measurements that can be derived from data sources (e.g., imagery) typically used to conduct landscape-level evaluations.

To produce this table, Vital Signs had to be aggregated into a reasonable number of categories and combined under a common name. In some cases, the exact intent or measure of the vital sign was unclear, and there are probably some mistakes in my interpretation of which networks identified particular vital signs. This is a general indication of intent, but there may be some misinterpretation of the detailed meaning of a vital sign.

Habitat fragmentation / pattern includes measures such as connectivity, distance between patches (vegetation or habitat), edge-to-perimeter indices, and other indices of the spatial characteristics of a landscape.

Land use pattern vs land use or land cover: some networks explicitly identified the *pattern* of patches (e.g., how the patches are arranged on the landscape) as distinct from just the total area. Decisions on whether to assign a network to either or both categories were made from the short list of vital signs and the demand for evaluation of land use pattern is under-reported.

There is potentially considerable overlap in the information contained in measures like Vegetation Composition / Structure and Land use or Pattern. In one case, the focus appears to be on the initial background matrix (native vegetation) and in the other case the imposed “patches” (anthropogenic disturbances). One of the challenges is to produce a monitoring program that effectively integrates measurements that may be targeted to different processes or ecosystem components. Any way that we can facilitate this integration will be extremely useful.

High-priority landscape or landscape-related vital signs identified by 9 networks (out of 32 total networks). January 2004.

VS Category	Vital Sign	Network
Land use / land cover pattern	External land use	APHN
	Resource extraction (internal)	APHN
	Harvest / extraction (trees?, minerals)	APHN NCPN
	Habitat fragmentation / pattern	APHN CUPN NCRN NCPN
	Land use pattern	APHN CUPN NCRN
	Land use / land cover change (does not specify pattern)	CAKN GRYN NCPN NCBN SFAN SODN
	Housing density	NCBN
	Snow / glacier coverage	CAKN
Vegetation composition / structure	Dominant vegetation types	APHN SFAN GRYN SODN
	Vegetation type spatial structure	CUPN NCRN
	Vegetation composition / assemblage change	NCBN SFAN CAKN GRYN SODN
	Forest interior habitat; area and spatial context	NCRN
Disturbance	Fire extent, severity, and frequency (current and historical)	APHN CAKN GRYN NCPN
	Non-fire regimes (wind, beaver, browsers/grazers, insects, flood)	APHN SFAN CAKN GRYN
	Exotic plants	APHN NCPN SODN
	Insects infestations (typically exotic)	NCRN NCPN
	Catastrophic events (floods, hurricanes, etc)	SFAN
	Local human impacts	CAKN NCPN
	Disturbance (not specific)	SODN
Animals	Beavers (lump with hydrology?)	GRYN
Topography	Shoreline topographic change (beach and marine)	NCBN SFAN
	Hillslope / soil erosion	NCPN
Hydrologic resources	Water consumption: agriculture or domestic	NCBN NCPN
	Hydrologic diversions / instream / reservoirs	NCPN
	Point source pollution	NCBN CAKN
	Channel morphology / classification	SODN
Other	Fertilizer consumption	NCBN
	Livestock populations	NCBN
	Viewshed	NCRN SFAN
	Road dust	CAKN
	Migrant impacts	SODN

Table 12-1. Assessment of indicators of landscape integrity (from Jones et al. 1996).

Indicator	Criterion										
	1	2	3	4	5	6	7	8	9	10	11
Ideal rating	H	L	H	H	H	H	H	H	H	-	H
Land Cover Composition and Pattern											
Land cover dominance	H	L	H	M	H	H	H	H	H	G	H
% tree cover	H	L	H	M	H	H	H	H	H	G	H
Land cover connectivity or fragmentation	H	L	H	M	H	H	H	H	H	GD	H
Land cover shape complexity	H	L	H	M	H	H	H	H	H	GD	H
% weeds	H	L	H	M	H	H	H	H	H	G	H
Land cover patch sizes	H	L	H	M	H	H	H	H	H	G	H
% of land cover types in protective status	H	L	H	M	H	H	H	H	H	GD	H
% of total amount of individual land cover types by farm or landcare area	H	L	H	M	H	H	H	H	H	G	H
% of total amount of individual land cover types at regional scale within catchment	H	L	H	M	H	H	H	H	H	G	H
% of paddocks on greater than 5% slope	H	L	H	M	H	H	H	H	H	GD	H
Riparian Extent and Distribution											
% of woody vegetation along streams/unit of stream distance	H	L	H	H	H	H	H	H	H	GD	H
Connectivity of woody along streams/unit of stream distance	H	L	H	M	H	H	H	H	H	GD	H
% of woody vegetation along streams by width class/unit of stream distance	H	L	H	H	H	H	H	H	H	GD	H
Ground Water											
Albedo change	H	L	H	H	H	H	H	H	H	GD	H
Topographical concavity variation	H	L	H	H	H	H	H	H	H	GD	H
Depth to watertable	H	M	H	L	H	L	M	L	H	D	H
Greenness Pattern											
NDVI pattern and change	H	L	H	M	H	M	M	L	H	G	H
NDVI expected versus observed based on soils, topography, vegetation and climate	H	L	H	M	H	M	M	L	H	G	H
NDVI pattern changes	H	L	H	M	H	M	M	L	H	G	H
Degree of Biphysical Constraint											
Farm position in catchmet relative to biophysical constraints	H	L	L	L	L	H	L	H	H	D	H
Sub-catchment position in catchment relative to biophysical constraints	H	L	L	L	M	H	L	H	H	D	H
Catchment position in region relative to biophysical constraints	H	L	L	L	H	H	L	H	H	D	H
Erosion Potential											H
Soil loss distribution	H	L	M	M	H	M	H	H	H	GD	H
% bare soil	H	L	H	H	H	H	H	H	H	GD	H
% of farms on erodible soils	H	L	H	H	H	H	L	H	H	D	H
Distance of agricultural patches from streams	H	L	H	H	H	H	L	H	H	D	H
% of paddocks on greater than 5% slope	H	L	H	M	H	H	H	H	H	GD	H

Selection criteria:
1. ease of capture (High, medium, low)
2. total cost/ha (H,M,L)
3. standard method available (H,M,L)
4. interpretation criteria available (H,M,L)
5. significant at catchment scale (H,M,L)
6. low error associated with measurement (H,M,L)
7. response to disturbance (H,M,L)
8. stable over period of measurement (H,M,L)
9. mappable (H,M,L)
10. generic (G), diagnostic (D) applications
11. context data available (H,M,L)

Note: Indicators selected to be included in the set of key indicators (Section Two) are shown in bold type.

Table 2. Description and range of values for landscape metrics used in this analysis. Calculation methods and details of each indicator can be found in Jones et al. (1997). Metrics were calculated for each watershed support area.

Metric	Explanation	Minimum	Maximum	Mean
Riparian agriculture (ripa)	Percent of watershed with agricultural land cover adjacent to stream edge. One pixel (30 × 30 m) wide.	0.04	58.5	18.5
Riparian forest (ripf)	Percent of watershed with forest land cover adjacent to stream edge. One pixel wide.	3.2	99.8	63.4
Forest fragmentation (ffrg)	Forest fragmentation index for watershed. Of all pairs of adjacent pixels in the watershed that contain at least one forest pixel, the percentage for which the other pixel is not forest.	0.6	79.5	17.4
Road density (rd)	Road density for watershed expressed as an average number of kilometers of roads per square kilometer of watershed.	81.7	494.1	179.1
Forest land cover (flc)	Percent of watershed with forest land cover.	1.3	99.6	58.4
Agricultural land cover (alc)	Percent of watershed with agricultural land cover (pasture/crops).	0.38	96.9	35.7
Agricultural land cover on steep slopes (ags3)	Percent of watershed with agriculture occurring on slopes greater than 3 percent.	0	52	12.5
Nitrate deposition (nd)	Estimated average annual wet deposition of nitrate (kg/ha × 100).	1249	2173	1758
Potential soil loss (poso)	Proportion of watershed with the potential for soil losses greater than 2240 kg/ha/yr.	0	67.8	33.2
Roads near streams (rxs)	Proportion of total stream length having roads within 30 m.	0	1.47	0.6
Slope gradient (sg)	Average percent slope gradient for watershed.	0	19.4	7.5
Slope gradient range (sgr)	Percent slope gradient range (maximum minus minimum) for watershed.	0	143	58.8
Slope gradient variance (sgv)	Percent slope gradient variance for watershed.	0	229	66
Urban land cover (purb)	Percent of watershed with urban land cover.	0.01	36.9	3.5
Wetland land cover (pwetl)	Percent of watershed with wetland land cover.	0	19.9	1.1
Barren land cover (pbar)	Percent of watershed with barren land cover. This includes quarry areas, coal mines, and transitional areas such as clear cut areas.	0	8.8	0.9

and sediment yield, but especially metrics of the amount of agriculture, riparian forests, atmospheric nitrate deposition, and roads in the watershed (Table 4, Figures 2 and 3). The greatest amount of variation explained by a landscape metric model was for total nitrate in streams ($r^2 = 0.86$, Table 4). This model included several significant landscape metrics, with the amount of agriculture in the watershed explaining 50% of the variation (positive association) and atmospheric nitrate deposition explaining 27% of the total variation (positive association, Table 4). The remaining landscape metrics in the model that explained relatively small, but significant portions of the total variation were related to roads, watershed slope, and the percentage of the watershed with urban land cover (Table 4).

Together, the proportion of total stream miles in the watershed with forest (riparian forest, negative association) and nitrate deposition (positive association),

Table I. Natural disturbances In North America. The kinds of disturbances vary geographically, and by topographical position and substrate (copied from P.S. White et al. 1999).	
Eastern mixed and deciduous forests	Gap dynamics: Runkle 1982,1985; Forcier 1975; Lorimer 1980
	Hurricane, catastrophic wind: Foster 1988, Foster and Boose 1992
	Fire: Komarek 1974, Harmon 1982,1984; Abrams 1992; Clark and Royall 1996
	Landslide: Hupp 1983
	Insects and pathogens: Schowalter 1985, Harmon et al.1983, Daughtry and Hibben 1994
	Ice storm: Lemon 1961, Whitncy and Johnson 1984
	Catastrophic drought: Hough and Forbes 1943
Southeastern pine forests	Fire, beetles: Komarek 1974, Rykiel et al.1988, Frost 1993
Appalachian spruce-fir forests	Gap dynamics, wind: White et al.1985a,b; Sprugel 1976
	Debris avalanche: Flaccus 1958
Central grasslands	Fire, grazing, burrowing animals: Vogl 1974, Collins 1987, Hobbs et aI. 1991, Vinton et aI. 1993 Catastrophic drought: Weaver 1968
Deserts	Rare rain storms, flash floods: Zedler 1981
Western conifer forests	
Rocky Mountains	Fire, insects: Knight 1987, Romme and Knight 1981, Romme 1982, Romme and Despain 1989, Veblen et aI.1994
	Cryogensis in alpine communities: Johnson and Billings 1962
Sierra Mountains	Fire: Kilgore and Taylor 1979, Stephenson et aI.1991, Stephenson 1996, Swetnam 1993
Pacific Northwest	Fire, windstorm: Stewart 1986, Franklin and Forman 1987, Hansen et aI. 1991
	Landslides: Swanson and Dyrness 1975
	Volcanic eruption: Franklin et aI.1985
Western shrublands	Fire: Biswel11974, Minnich 1983, Christensen 1985
	Debris flows: Biswell 1974
Boreal forest	Fire, insects: HeiIlselman 1973, 1981; Dansereau and Bergeron 1993
Arctic tundra	Cryogenesis: Churchill and Hanson 1958
Subtropical areas	Freeze damage: Silberbauer-Gottsberger et aI. 1977
Lakes	Fluctuating water levels: Shipley et al. 1991
	Ice battering on shorelines: Raup 1975
Streams	Floods and erosion: Hemphill and Cooper 1983, Resh et aI.1988, Pringle et aI.1988
	Beaver: Ives 1942
	Debris flows: Lamberti et aI. 1991
Coastal areas	Dune movement: Schroeder et aI.1976
	Hurricanes and other storms: Chabrek and Palmisano 1973
	Salinity changes: Chabrek and Palmisano 1973
Rocky intertidal communities	Wave action, storms, predation, dessication, drift log battering: Paine and Levin 1981; Sousa 1984,1985; Dayton 1971
Mangroves	Hurricanes, salinity changes: Thorn 1967

From: White, P. S. and A. Jentsch. 2001. The search for generality in studies of disturbance and ecosystem dynamics. Progress in Botany 62:399-449.

Figure 15. Diagram depicting large scale influences and linkages between land use change disturbance and ecological mechanisms (stressors).

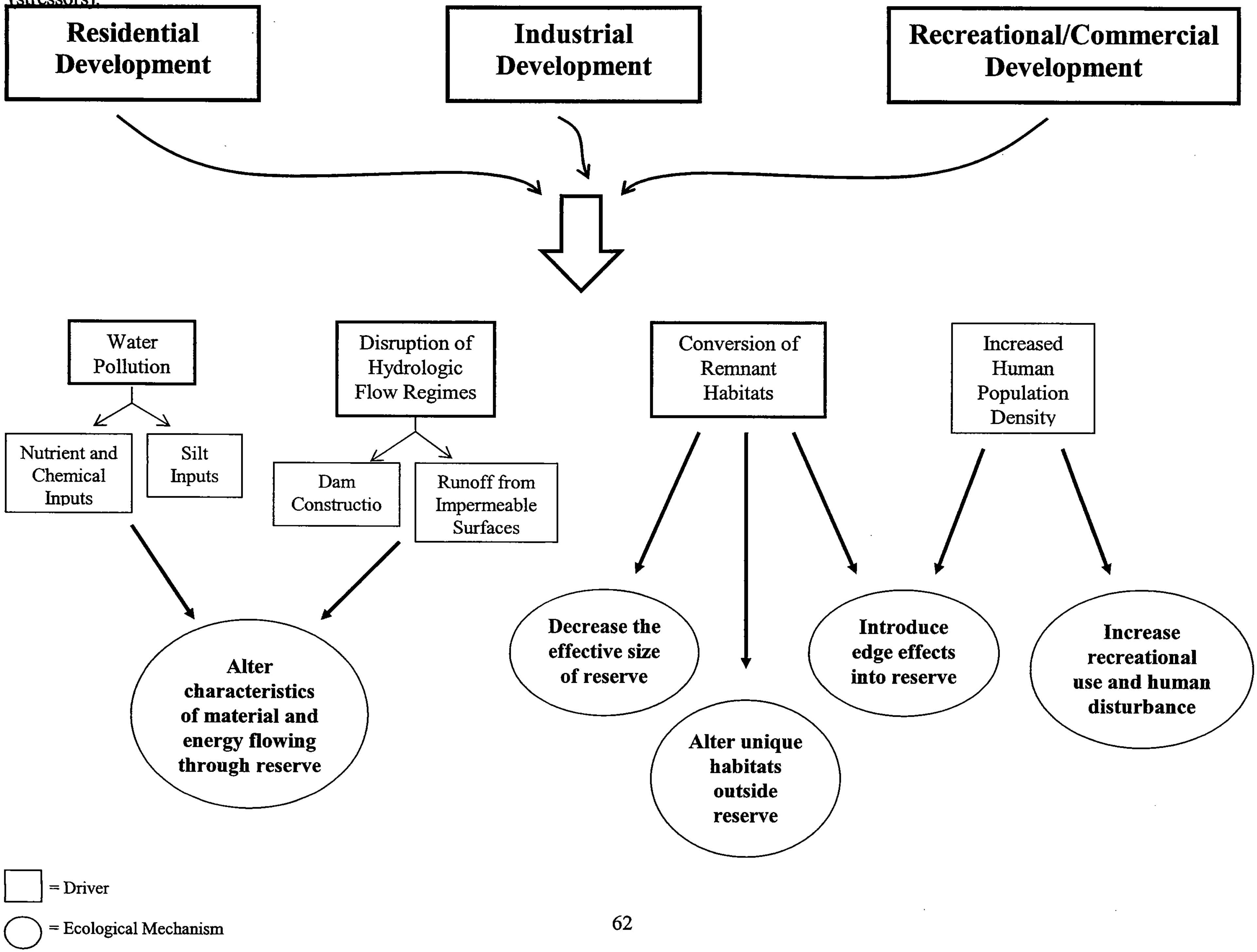

Figure 16a. Conceptual model diagram showing relationships between specific drivers and ecological functioning.

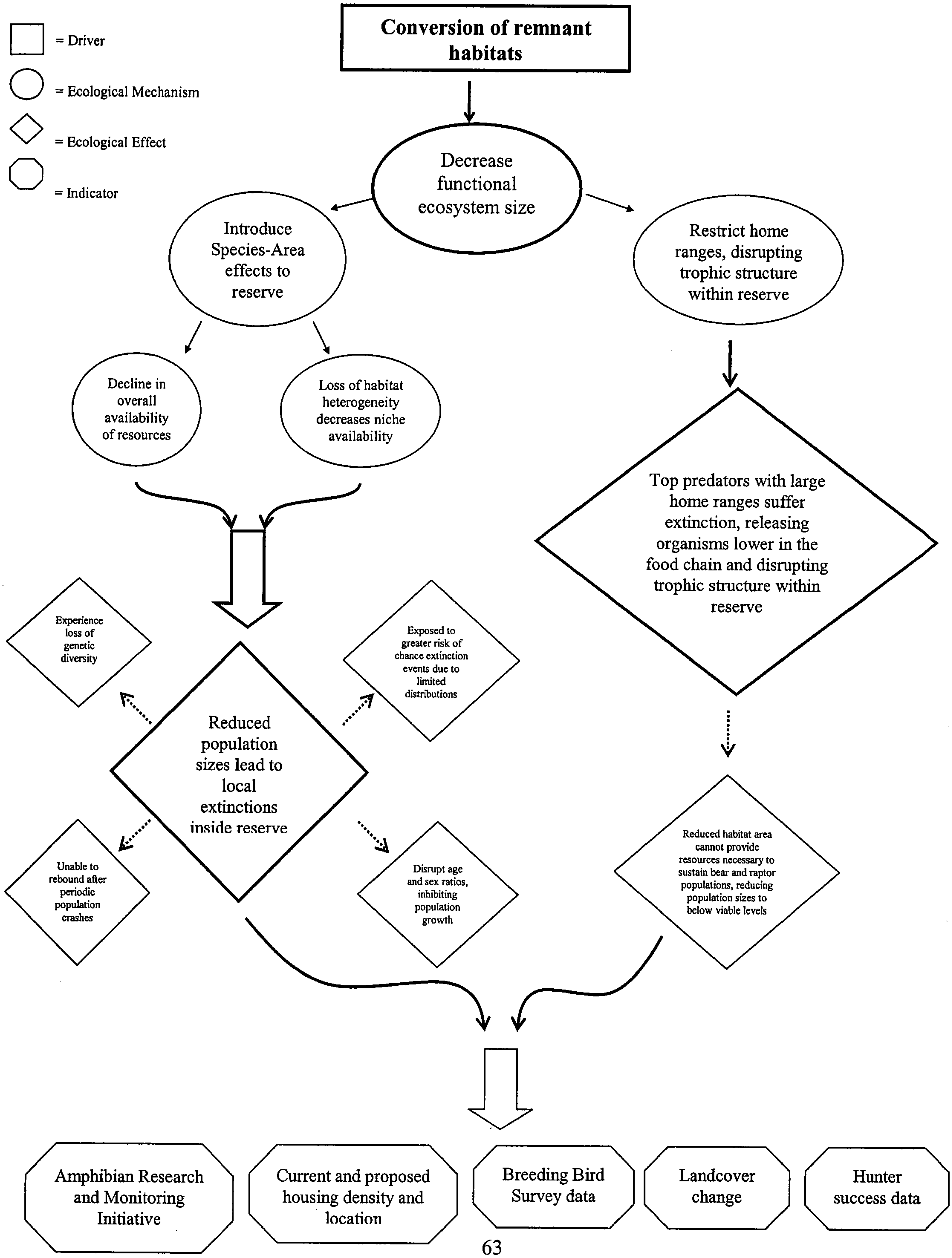

Figure 16b. Conceptual model diagram showing relationships between specific drivers and ecological functioning.

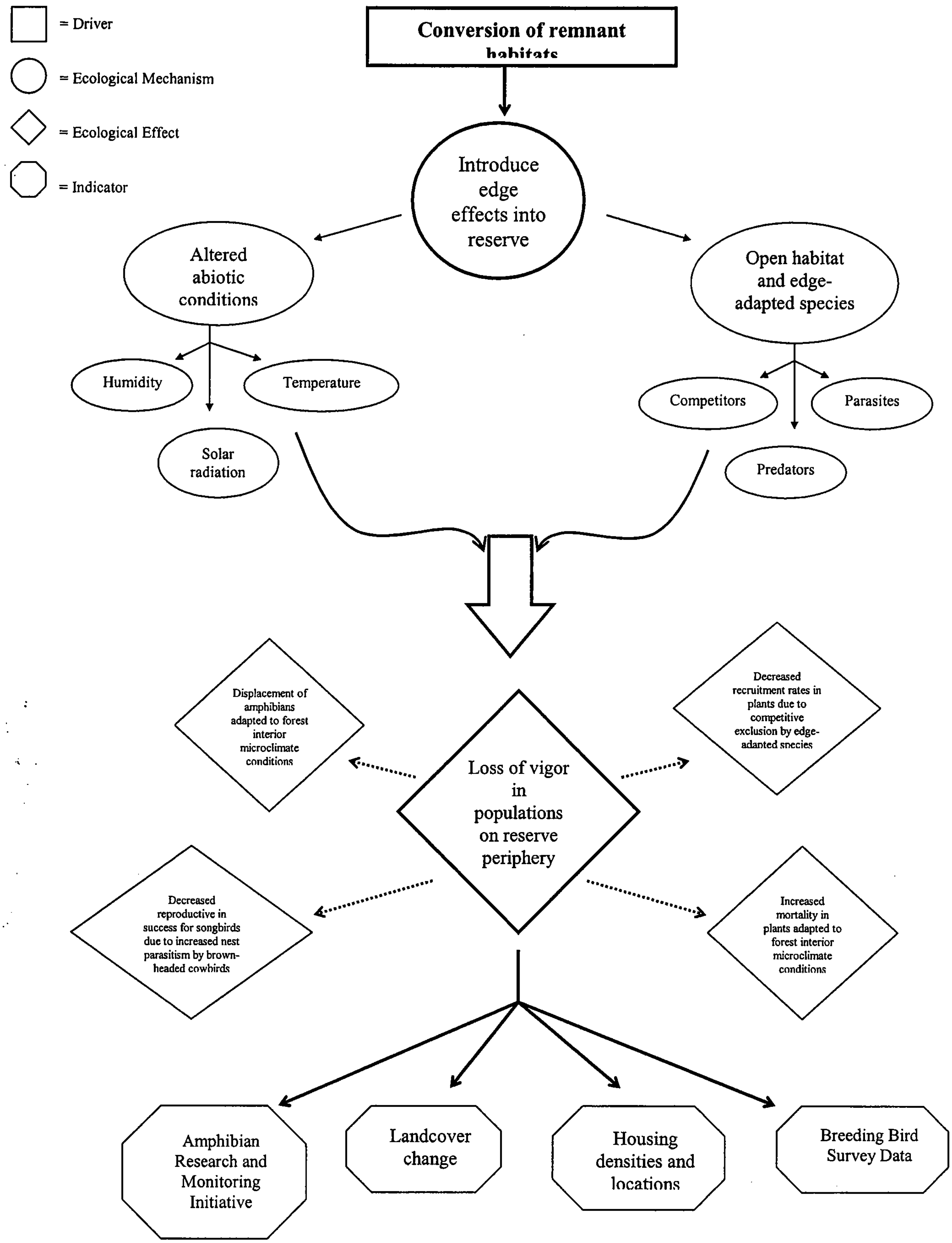

Figure 16c. Conceptual model diagram showing relationships between specific drivers and ecological functioning.

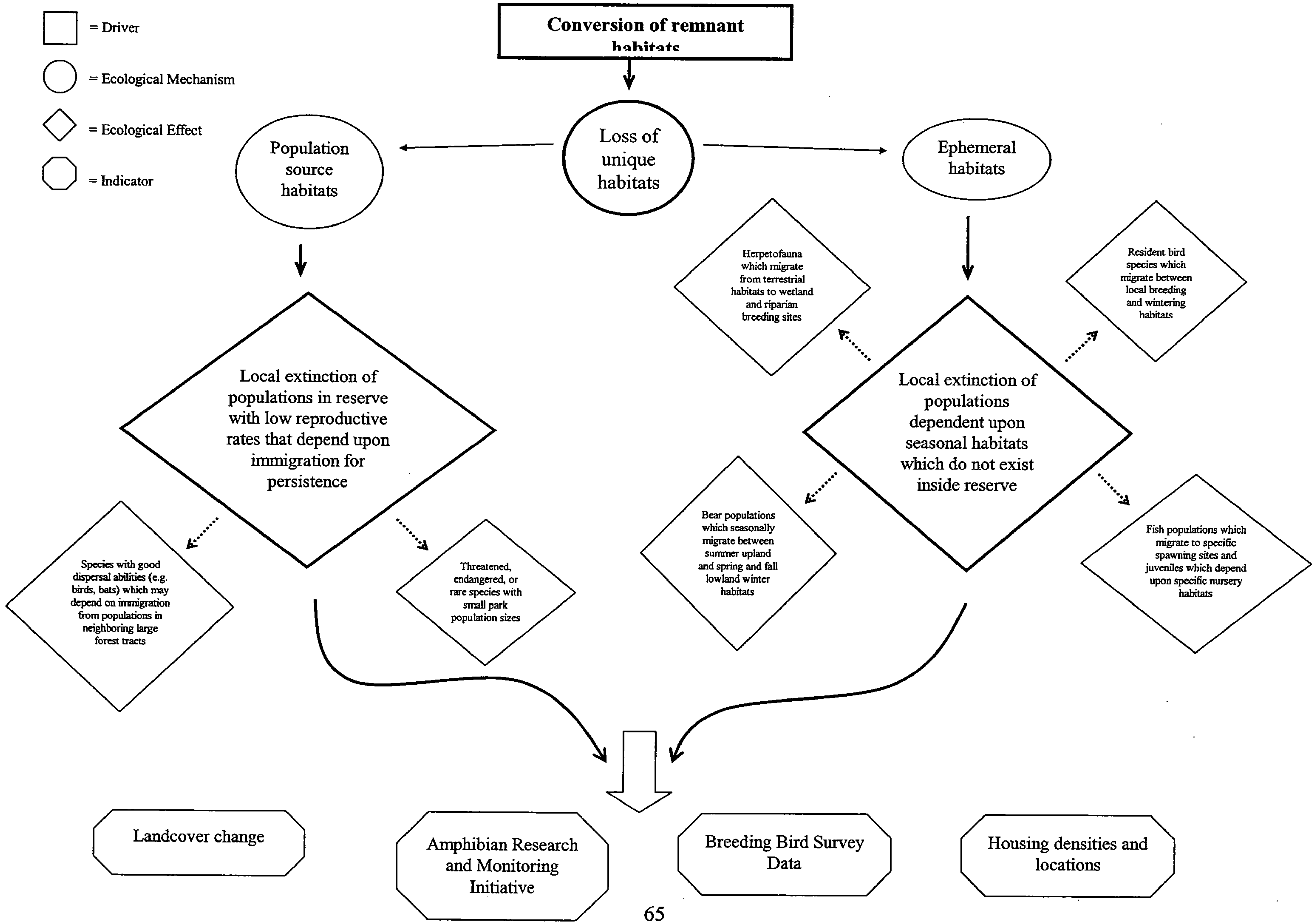

Figure 16d. Conceptual model diagram showing relationships between specific drivers and ecological functioning.

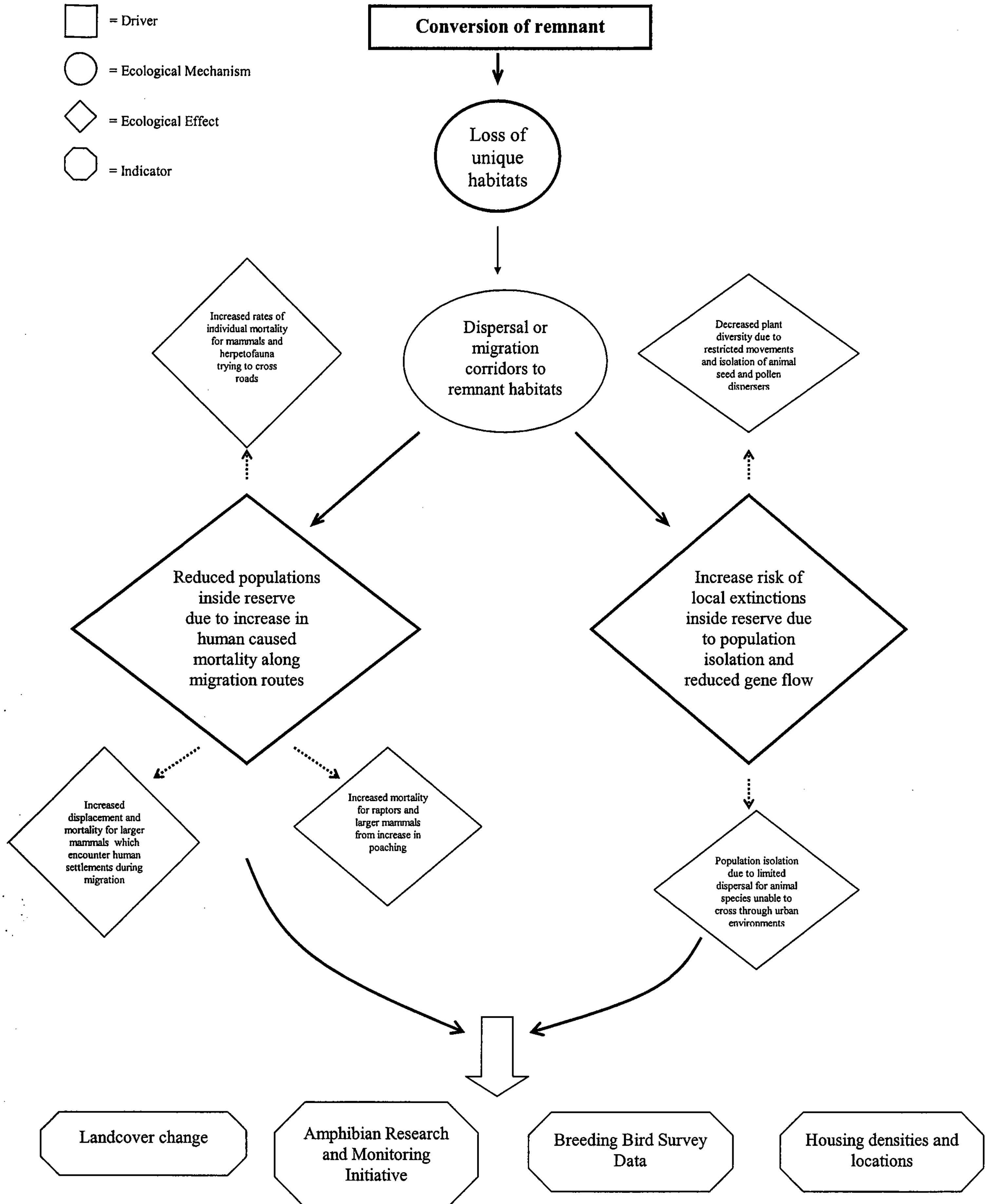

Figure 16e. Conceptual model diagram showing relationships between specific drivers and ecological functioning.

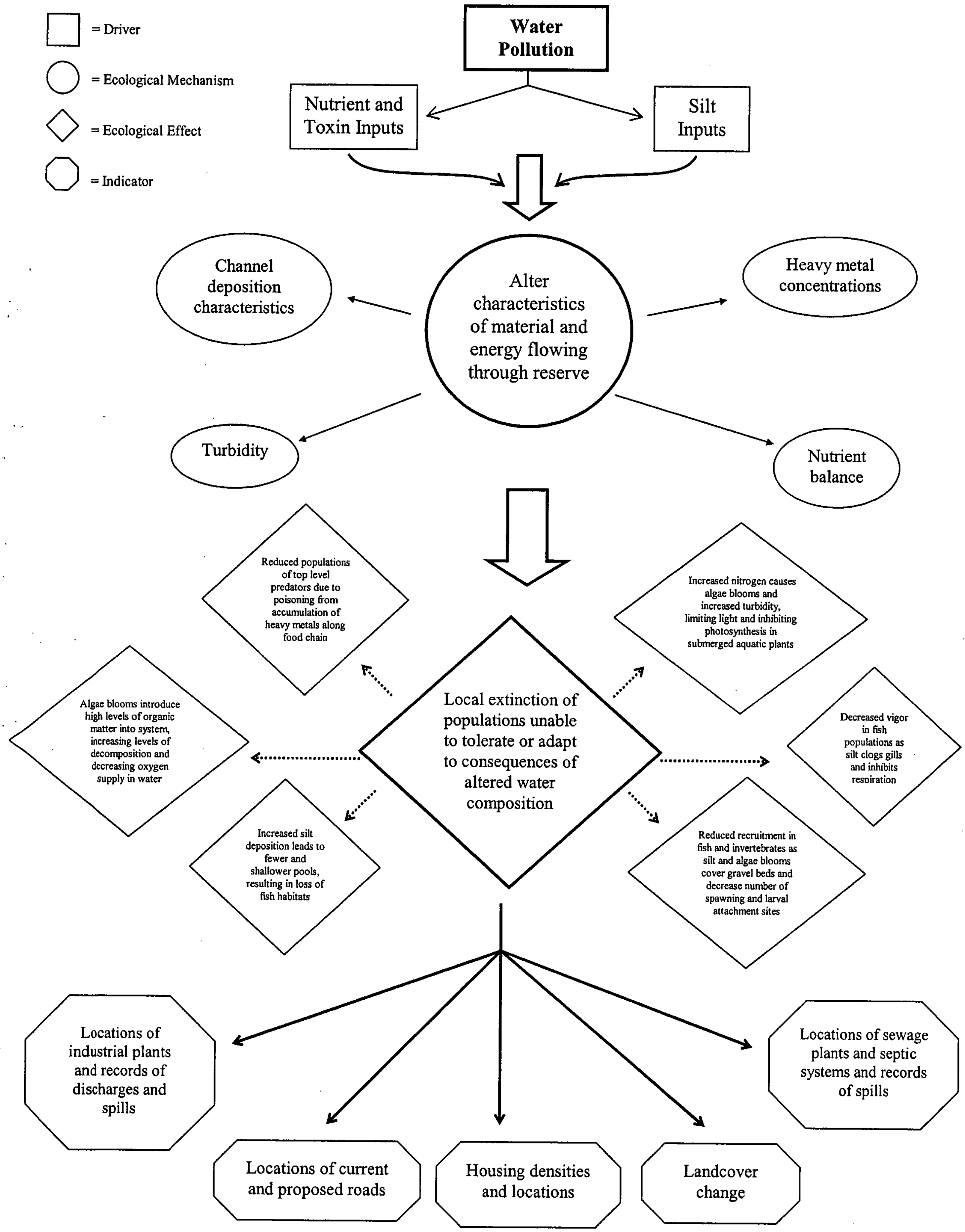

Figure 16f. Conceptual model diagram showing relationships between specific drivers and ecological functioning.

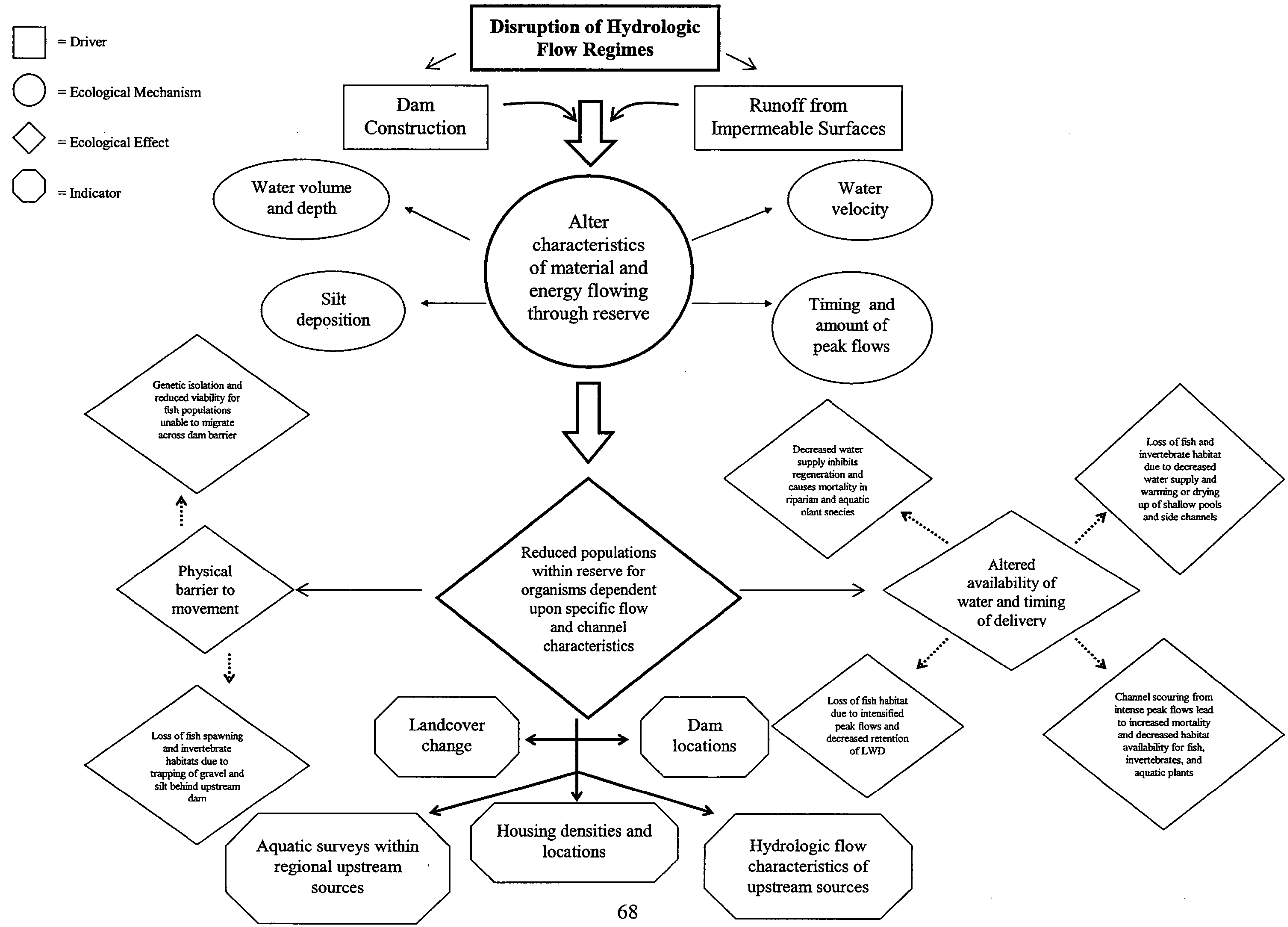

Figure 16g. Conceptual model diagram showing relationships between specific drivers and ecological functioning.

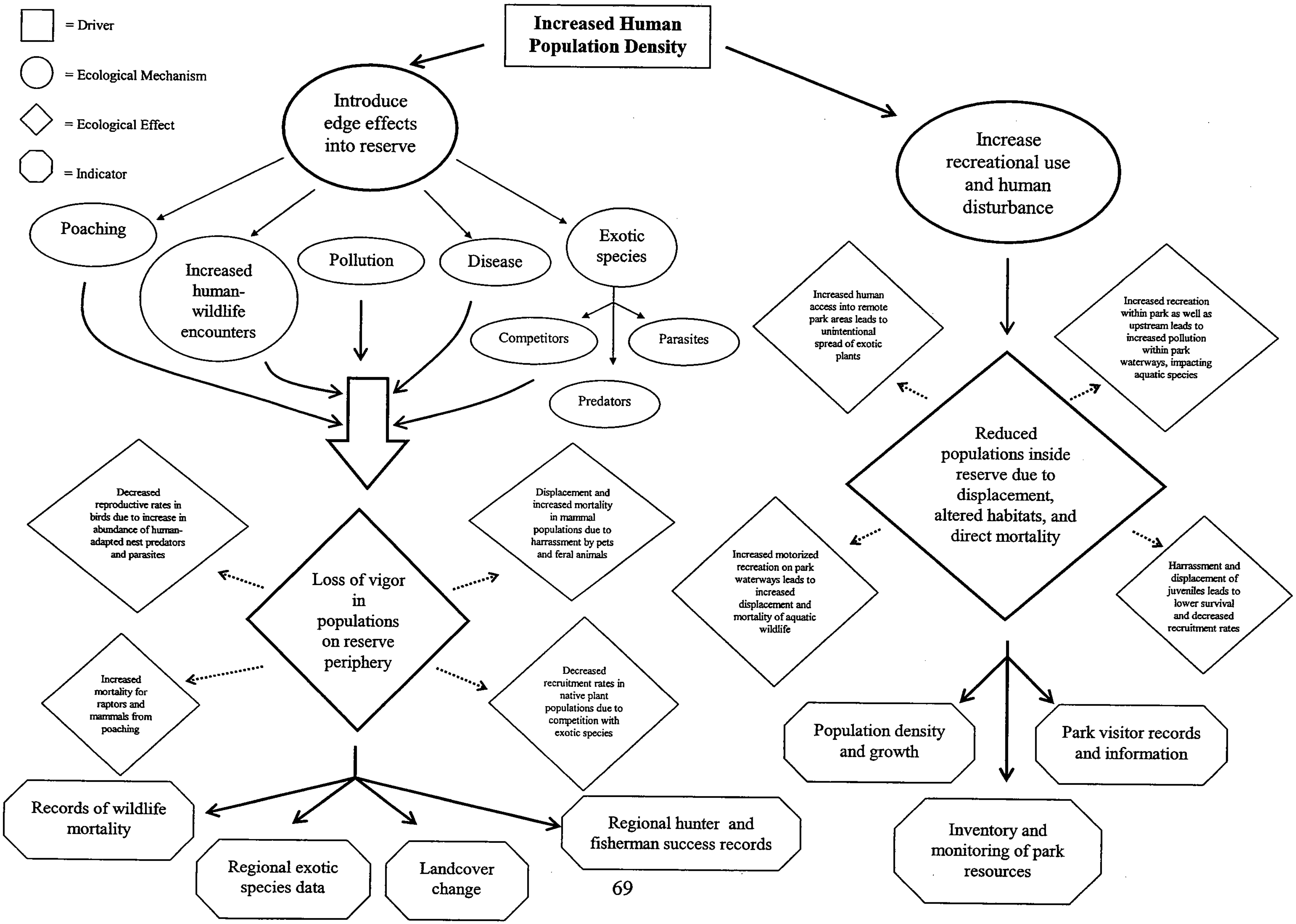

Table 3. Spatial datasets used for characterization of current landscape and land use change over time.

Spatial Dataset	*Source*	*Source Location*	*Measure*	*Scale*
Housing and population density	U.S. Census Bureau (2000)	www.census.gov	Average number per square mile	County
Water discharge permit records	State (AR, MO, IA, IN, OH, KY) Departments' of Environmental Quality; U.S. EPA (2003)	www.epa.gov/enviro/	Number of industrial (NPDES) water discharge sites	County
Land cover	USGS, National Land Cover Dataset (1992)	http://edc.usgs.gov	Land cover classified into cover types depicting industrial, urban, wetlands, shrub, pasture, crops, and forest. Percent of each land cover type measured as % of total pixels.	30 meter pixel
Conventional water pollution	EPA National Watershed Characterization (1999)	www.epa.gov/iwi/	Percent of time water samples exceed non-toxic (nutrients, total suspended solids, biochemical oxygen, etc.) pollutant limits	Watershed
Hydrologic modification	EPA National Watershed Characterization (1999)	www.epa.gov/iwi/	Relative degree of modification based on reservoir storage capacities of existing dams (at least 50 feet tall)	Watershed
Cities	National Atlas of the United States (2000)	www.nationalatlas.gov	Cities (with at least 1000 people) by population size	City
Overall population change	U.S. Census Bureau (1950 -2000)	www.census.gov	Percent population growth	County
Change in farmland acreage	U.S. Census of Agriculture (1950 – 1997); State (MO, IA, IN, OH, KY) Agriculture Statistics Services	www.nass.usda.gov/census/ http://agebb.missouri.edu www.nass.usda.gov/ia/ www.nass.usda.gov/in/ www.nass.usda.gov/ky/ 1950 Census of Agriculture (Published by U.S. Census Bureau-Ag. Division, by state)	Percent change in "acres in farms"	County
Trends in major dam construction	U.S. Army Corp of Engineers and FEMA, National Inventory of Dams (1996)	www.nationalatlas.gov	Number of major dams built per decade, based on extrapolation from "date of construction"	Individual dam
Change in housing density	U.S. Census Bureau, "Profile of Selected Housing Characteristics" (2000)	www.census.gov	Number of houses built per decade from 1950-2000, based on extrapolation from "Year Structure Built" category	County

Landscape Analysis and Assessment — Overview

Office of Research and Development

National Exposure Research Laboratory

Environmental Sciences Division

Landscape Ecology Branch

Background

In the past, environmental policy generally reflected a reactive response to environmental perturbations with management efforts focused on short-term, local-scale problems such as pollutant abatement. The 1980s witnessed increased interest in protecting whole ecosystems from chronic environmental problems, but these were often partitioned in relation to specific media, e.g., water, air, or soil pollution.

Currently, environmental management philosophy is evolving toward examination of critical environmental problems over larger spatial scales and assessment of the cumulative risk resulting from multiple stressors. Concern over the condition of communities, watersheds, and ecoregions has received considerable attention. Subsequently, the U.S. Environmental Protection Agency initiated a landscape research program in 1992 to develop and test multi-scaled vulnerability assessment approaches.

Goals

Through development and application of landscape assessment approaches, the landscapes program is designed to enhance the ability of environmental managers and the public to:

- determine the status and trends of ecological resources at multiple scales;
- evaluate how conditions at a community scale are influenced by broader-scale landscape patterns and characteristics;
- evaluate impacts of multiple stressors on ecological resources;
- evaluate and prioritize the vulnerability of ecological resources to impairment due to a range of stressors at multiple scales;
- formulate a variety of landscape planning options within and among scales to reduce vulnerability of ecological resources to impairment, and to enhance and restore specific ecological resources;
- develop products, such as regional and watershed assessments, analysis tools, digital maps, and databases, for a variety of audiences.

Conceptual Approach

The landscapes program uses landscape ecology, i.e., the study of the distribution patterns of communities and ecosystems, the ecological processes that effect those

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patterns, and changes in both pattern and process over time, as its foundation. Research is focused on the interaction between landscape patterns and ecological processes, especially as they affect the natural flows of water, energy, nutrients, and biota in the environment. Landscape pattern metrics related to size, shape, and connectivity are used as indicators of ecological processes and stressors. These indicators are related to conditions in specific ecological resources through application of models and empirical studies, and therefore provide the basis for assessments of watershed condition (water quality, quantity, and vulnerability to flooding), landscape resilience (ability to sustain ecological goods and services when subjected to combinations of anthropogenic and natural stress), and biodiversity (wildlife habitat).

The latest in available technology relative to remote sensing, geographic information systems, and spatial statistics is being used. Remotely placed scanners, such as the Landsat satellites, provide data with: (1) broad temporal frequency, (2) complete spatial coverage, (3) ease and economy of acquisition, (4) capability to integrate measurements of ecosystem condition that are derived from site and remote sensing methods, and (5) an ability to assess ecological conditions at multiple scales. Landscape pattern metrics and indicators are derived from these data by using commercial and custom-designed spatial statistics software.

Implementation

The program is proceeding simultaneously along two lines: (1) a research component to develop and test landscape indicators and assessment protocols, and (2) an implementation component to demonstrate the application of landscape analysis protocols to multiple-scale, ecological assessments. The research and implementation agendas are being accomplished through regional studies throughout the United States, e.g., Mid-Atlantic Region. An overall research strategy *(Landscape Monitoring and Assessment Research Plan* - 1994, *EPA/620/R-94/009, 1994)* originally set forth a specific research agenda to resolve key technical issues, including sampling design, indicator development, and assessment protocols. This was later refined in a 10-year research strategy to develop *A National Assessment of Landscape Change and Impacts to Aquatic Resources (EPA/600/R-00/001)* published in January 2000.

Landscape indicators are in various degrees of development. Some are fully field tested and ready for immediate use; others are preliminary concepts developed from the theoretical basis of landscape ecology. A number of journal articles have been published by the landscapes program that address landscape indicator and assessment issues.

The landscapes program has developed an *"Atlas"* concept to communicate its analysis results to a variety of users. A landscape atlas consists of a set of indicators mapped across multiple scales. The maps give the reader an idea of the spatial distribution of landscape condition relative to specific environmental values at multiple scales. A demonstration of this concept, *An Ecological Assessment of the United States Mid-Atlantic Region (EPA/600/R-97/130),* was published in November 1997.

Anticipated Contributions

Two major types of contributions should result from the program: (1) a set of key scientific findings regarding the application and interpretation of landscape indicators at multiple scales, and (2) a landscape assessment framework to analyze ecological resources that contribute to multi-scaled ecological vulnerability and risk reduction assessments.

The landscape assessment framework and methodologies should provide a number of benefits to environmental managers and the public:

- *An understanding of how conditions at a community level are influenced and constrained by broader-scale conditions of watersheds and ecoregions.*
- *An ability to address a range of environmental problems that have inherently different scales.*
- *An ability to address cumulative impacts to ecological resources.*
- *A framework for regional vulnerability assessments.*
- *An ability to communicate analysis and assessment results to a wide range of audiences.*

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